

## BARRIER REGION FOR OPTOELECTRONIC DEVICES

### FIELD OF THE INVENTION

The present invention relates to structures that protect organic optoelectronic devices from chemical species in the surrounding environment.

### BACKGROUND OF THE INVENTION

Organic optoelectronic devices, including circuits, such as organic light emitting diodes, organic electrochromic displays, organic photovoltaic devices and organic thin film transistors, are known in the art and are becoming increasingly important from an economic standpoint.

As a specific example, organic light emitting devices ("OLEDs"), including both polymer and small-molecule OLEDs, are potential candidates for a great variety of virtual- and direct-view type displays, such as lap-top computers, televisions, digital watches, telephones, pagers, cellular telephones, calculators and the like. Unlike inorganic semiconductor light emitting devices, organic light emitting devices are generally simple and relatively easy and inexpensive to fabricate. Also, OLEDs readily lend themselves to applications requiring a wide variety of colors and to applications that concern large-area devices. In general, two-dimensional OLED arrays for imaging applications are known in the art and are typically composed of a plurality of OLEDs (one or more of which forms a pixel) arranged in rows and columns. Each individual OLED in the array is typically constructed with a first transparent anode (such as ITO), an organic electroluminescent layer on the first electrode, and a metallic cathode on the organic electroluminescent medium. Other OLED architectures are also known in the art such as transparent OLEDs (having a transparent cathode contact), and inverted OLEDs. Substrate materials may include glass, plastic, metal foil, silicon wafers, etc.

In forming an OLED, a layer of reactive metal is typically utilized as the cathode to ensure efficient electron injection and low operating voltages. However, reactive metals and their interface with the organic material are susceptible to oxygen and moisture, which can severely limit the lifetime of the devices. Moisture and oxygen are also known to produce other deleterious effects. For example, moisture and oxygen are known to increase "dark spot areas" in connection with OLEDs.

Components of various other organic optoelectronic devices (e.g., organic electrochromic displays, organic photovoltaic devices and organic thin film transistors) are likewise susceptible to attack from exterior environmental species, including water and oxygen.

### BRIEF SUMMARY OF THE INVENTION

The above and other challenges are addressed by the present invention.

According to an embodiment of the present invention, an organic optoelectronic device structure is provided that comprises: (a) a first barrier region comprising (i) a first composite layer stack and (ii) a second composite layer stack attached to the first composite layer stack, (b) an organic optoelectronic device selected from an organic light emitting diode, an organic electrochromic display, an organic photovoltaic device and an organic thin film transistor; and (c) at least one additional barrier region, wherein

the at least one additional barrier region cooperates with the first barrier region to restrict transmission of water and oxygen to the optoelectronic device from an outer environment. The first composite layer stack comprises a first polymer substrate layer, at least one first planarizing layer and at least one first high-density layer, while the second composite layer stack comprises a second polymer substrate layer, at least one second planarizing layer and at least one second high-density layer.

The first and second polymer substrate layers can be of the same material composition or different material compositions. Moreover, the first and second high-density layers can be of the same material composition; or at least one of the first and second high-density layers can be of a first material composition, while at least one other of these layers is of a second material composition. Similarly, the first and second planarizing layers can be of the same material composition; or at least one of the first and second planarizing layers can be of a first material composition, while at least one other of these layers is of a second material composition.

In some embodiments, the first and second composite stacks are attached to one another via one of the first and second planarizing layers, while in other embodiments, an adhesive layer is provided between the first and second composite stacks.

Numerous configurations are possible. For example, the at least one first planarizing layer, the at least one first high-density layer, the at least one second planarizing layer and the at least one second high-density layer can be disposed between the first polymer substrate layer and the second polymer substrate layer. As another example, these layers can be arranged such that (i) the at least one first planarizing layer and the at least one first high-density layer are disposed over the first polymer substrate layer, (ii) the second polymer substrate layer is disposed over the at least one first planarizing layer and the at least one first high-density layer, and (iii) the at least one second planarizing layer and the at least one second high-density layer are disposed over the second polymer layer.

Preferably, at least one of the first and second composite layer stacks will comprise two or more planarizing layers and two or more high-density layers. More preferably, at least one of the first and second composite layer stacks will comprise an alternating series of two or more planarizing layers and two or more high-density layers.

Additional composite layer stacks can be provided. For example, the first barrier region can further comprise a third composite layer stack attached to the second composite layer stack, in which case the third composite layer stack comprises a third polymer substrate layer, at least one third planarizing layer and at least one third high-density layer.

Preferably, (a) the planarizing layers comprise a material selected from fluorinated polymers, parylenes, cyclotenes and polyacrylates, and (b) the high-density layers comprise a material selected from silicon oxide, silicon nitride, metal oxides (such as aluminum oxide, indium tin oxide and zinc indium tin oxide), metal nitrides, metal carbides, metal oxynitrides. The polymer substrate layers preferably comprise a material selected from a fluorocarbon polymer, a polyethersulphone, a polyimide, a polyolefin (such as a cyclic olefin copolymer), and a polyester (such as polyethylene terephthalate).

The present invention is also directed to methods of forming an organic optoelectronic device structure. According to an embodiment of the invention, a first composite layer stack comprising a first polymer substrate layer, at least